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Technical efficiency and its determinants in sugarcane production among smallholder sugarcane farmers in Malava sub-county, Kenya

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The aim of the study was to determine the farm level technical efficiency and its determinants among smallholder sugarcane farmers in Malava Sub-county, Western Kenya. Primary data were collected using questionnaires from a sample of 384 farmers through systematic random sampling. The study applied stochastic frontier analysis and Tobit regression analysis using computer software STATA. The results found that technical efficiency of sugarcane farmers ranges from almost zero to 0.9829, with mean value of 0.7069, implying that an average farmer could increase sugarcane productivity by 29.31% at the existing level of resources. Maximum likelihood estimate of technical efficiency depicted that the use of fertilizer, labour, seed-cane and farm size are positive and significant at 1% level in determining technical efficiency. Tobit regression analysis showed that education, farming experience, family size, credit access and extension services were positive and significant in contributing to technical efficiency. However, age of the farmer, farm distance from home and contract engagement was negatively influencing technical efficiency. The study recommends the Kenyan government to formulate policies that ensure provision of quality extension services, increased credit access and education among smallholder sugarcane farmers. The results also recommended the need for a review of the existing contract engagement policies among sugarcane farmers.

Key words: Technical efficiency, stochastic frontier analysis, tobit, sugarcane.

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is one of the major crops grown in the world due to its multiple uses in daily life of any nation including nutritional and economic sustenance. Sugarcane contributes to about 80% of the total sugar produced in the world (Rumánková and Smutka, 2013). Brazil is the largest producer of sugarcane in the world with an annual production of about 768,678,382 metric tonnes which is followed by India that produces 348, 448,000 metric tonnes per year (FAOSTAT, 2016). Other countries which have shown high production of sugarcane are China and Thailand whose annual production is 123,059,739 and

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100,100,000 metric tonnes respectively (FAOSTAT, 2016).

African countries contribute about 5% of the total world sugar of which 80% is contributed by Sub-Saharan African countries (Travella and Oliveira, 2017). The major Sub-Saharan African countries where sugarcane crop is grown are South Africa, Sudan, Swaziland, Zambia, Mauritius and Kenya. These countries accounts for more than half of African total sugarcane production (Travella and Oliveira, 2017).

In Kenya, sugarcane is extensively planted in Western part of the Country. Production of sugarcane in Kenya is one of the major agricultural activities contributing to the national economic growth alongside tea, coffee, horticultural crops and maize (Waswa et al., 2012). The contribution of the Kenyan sugarcane sector towards the total agricultural gross domestic product (GDP) is about 15% with 25% of the Kenyan people relying directly and indirectly on sugarcane production for their living (Wekesa et al., 2015). Malava Sub-County which is one of the areas where sugarcane is the main cash crop has the highest number of people who depend on sugarcane activity for their living (Kenya Sugar Board, 2014). This Sub-County has two milling factories which are West Kenya Sugar Factory and Butali Sugar Mills.

However, despite the importance of sugarcane sector to the Kenyan economy, production of sugarcane has been deteriorating over the years (Mulianga et al., 2015). On average, the current production of sugarcane is about 60.52 tonnes per hectare (Kenya Sugar Board, 2014) which is low as compared to 90.86 tonnes per hectare in the year 1996 (Wolfgang and Owegi, 2012). Currently, the domestic demand is higher than production capacity in the Country whereby the production is about 550,000 tonnes of sugar per year against the domestic consumption of about 800,000 tonnes of sugar per year (Wawire and Ouma, 2013). As such, the Kenyan government has been heavily investing in this sector in order to obtain the optimum production and become self-sufficient in sugar production. However, this objective has never been met since the potential output is still not achieved in most of the sugarcane growing areas. Kenya being a developing Country is however constrained by production resources. For this reason, the achievement of technical efficiency at farm level would be the best complement to all efforts in attaining the optimum and self-sufficiency in sugarcane production. Efficiency in agricultural production refers to the choice of using the limited agricultural resources in an optimal way. The scope of production in crop farming can be sustained through efficient use of scarce resources in the economy. It has been widely argued that efficiency is the center of farm production (Awunyo-Vitor et al., 2016; Severini and Sorrentino, 2017). The objective of this study was therefore to determine technical efficiency and the effect of selected socioeconomic factors on efficiency among smallholder sugarcane farmers in Malava Sub-county.

MATERIALS AND METHODS

Description of study area

The study was conducted in Malava Sub-County which is one of the twelve Sub-counties of Kakamega County in Kenya. Malava Sub-County is mainly located in Lower Midland (LM) Zone 2-3 and Upper Midland (UM) Zone 4 Agro-ecological zones (Jaetzold et al., 2005) where the main economic activity is the growing of sugarcane as a cash crop. The area experiences two distinct rainy seasons. Long rain is experienced from March to July while short rains occur from September to December, with a short dry season that occur from January to February. This Sub-County has seven administrative units (Wards) which are; East Kabras, West Kabras, Chemuche, Manda-Shivanga, South Kabras, Butali-Chegulo and Shirugu-Mugai (IEBC, 2017).

Sample procedure and sample size

The sample size for this study was 384 respondents who were determined through Fischers formula given by Kothari (2004) as indicated in Equation 1.

$$\mathrm{n} = \frac{z^2(p)(q)}{\varepsilon^2} \quad (1)$$

Where, n is the sample size, z is equal to 1.96 which is the tabulated Z value for 95% confidence level, p is the sample proportion where 0.5 is the highest that can produce at least the desired precision while ε is the margin of error which is 0.05 since the estimate of the study will be within 5% of the true value.

Using Equation 1 above and assuming 50% probability that the respondent has the characteristic being measured, the sample size was determined as shown below;

$$\mathrm{n} = \frac{1.96^2(0.5)(1-0.5)}{0.05^2} = 384 \quad (2)$$

All the seven administrative units (Wards) in Malava Sub-county were purposively selected due to their agrarian potential for sugarcane production. The sample size of respondents from each administrative unit was selected through a proportional sampling allocation technique (Cochran, 1977) as shown below:

$$n_i = \frac{N_i \times \mathrm{n}}{\mathrm{N}} \quad (3)$$

Where, n_i is the number of sugarcane farmers interviewed in the selected wards, N_i is the total number of the sugarcane farmers in the selected Ward, n is the sample size for the study while N is the total number of sugarcane farmers in the area of study.

A systematic random sampling technique was applied to select farmers to be interviewed in each Ward.

Method of data collection

This study used structured questionnaire to collect primary data from respondents on sugarcane production. Trained enumerators were employed to facilitate the process of data collection under the supervision of the researcher. Detailed information from the selected farm households were collected on demographic and socio-economic factors, farm characteristics, input use, production, institutional and policy related variables. The survey was carried out from July to August, 2019.

Data analysis

The study applied both descriptive and econometric statistics to achieve its objective. Descriptive analysis such as mean, standard deviation, minimum, maximum, percentage and frequency counts were used to summarize socio-economic and demographic characteristics of the respondents, input and output variables, and frequency distribution of technical efficiency levels. Econometric techniques such as stochastic frontier analysis technique and tobit regression were applied to analyze technical efficiency (TE) among the selected households and the effect of the selected socioeconomic factors on TE.

Analytical framework

Several approaches have been developed to estimate efficiency of farms including econometric and mathematical programming approaches. However, there are two frontier model that are commonly applied; the Stochastic Frontier Model (SFM) and Data Envelopment Analysis (DEA). The choice of a specific model depends on the objective of the study, kind of data and assumptions (Erkoc, 2014). SFM has been commonly used in determination of agricultural efficiency since DEA has been widely criticized due to its assumption that all deviation from the frontier are associated with inefficiency. These assumptions are hard to be accepted due to inherent variability of agricultural production as a result of weather variation, pest and disease outbreak (Coelli et al., 2005). SFM which was first introduced by Aigner et al. (1977) is prefered due to its ability to measure efficiency in the presence of statistical noise. This model has got two error terms where one accounts for the existing measurement error in production and the other one is as a result of the estimation of frontier production function. According to Aigner et al. (1977), the parametric frontier is presented as:

$$Y_i = f(X_i, \beta) + V_i - U_i \quad (4)$$

Where, V_i is the error component which accounts for the measurement error in the output variable due to the weather, combined effect of the unobserved input on production, errors in the observation and measuring of data and U_i is the error component that accounts for the existence of inefficiency in production. Y_i is the quantity of output, X_i refers to quantity of inputs, βs are the unknown parameters to be estimated, which represents elasticities of inputs while f represent the production frontier function.

The estimated technical efficiency of ith farmer is determined as the ratio of the observed output for the ith farm relative to the potential output. This can be illustrated as shown in Equation 5.

$$TE_i = \frac{Y}{Y^*} = \frac{exp(X_i\beta + V_i - U_i)}{exp(X_i\beta + V_i)} = \exp(-U_i) \quad (5)$$

Where, Y is the observed output and Y^* is the potential or frontier output.

Literature has revealed that stochastic frontier model has been broadly used to determine efficiency in agriculture. For instance, Kassa et al. (2019), Dube et al. (2018), Mamo et al. (2018) and Getahun and Geta (2017) used SFM to determine the technical efficiency levels in production of teff, potato, wheat and barley respectively in Ethiopia. The technique was also applied by Yegon et al. (2015) to evaluate the technical efficiency of smallholder soybean production in Kenya.

Model specification for technical efficiency

The current study applied stochastic frontier model to determine technical efficiency within the framework of Cobb-Douglas production function. Following the specification of the stochastic Cobb-Douglas production model, the data was fitted as below:

$$\ln Y_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + V_i - U_i \quad (6)$$

Where, ln = logarithm to base e, β_0= constant which represents the intercept of production function, β_1 to β_4 = unknown parameter that were established which are also the output elasticities of amount of fertilizer, labour, seed-cane and farm size respectively. Y_i = quantity of sugarcane in tonnes, V_i = two sided random error representing stochastic effect beyond farmer's control, measurement errors and other statistical noise and U_i = a non-negative random variable representing technical inefficiency of sugarcane farmer. X_1, X_2, X_3 and X_4 are the amounts of fertilizer, labour, seed-cane and farm size respectively.

Following Coelli et al. (2005) and Bi (2004), the model given in the Equation 6 was estimated using the maximum likelihood estimates (MLE). MLE provides the rationale estimates for unknown parameter (β), gamma (Υ) and sigma squared (σ^2).

Model specification for the effect of socioeconomic factors on technical efficiency

The relationship between socioeconomic factors and technical efficiency was analyzed using tobit regression model since technical efficiency has a lower limit of zero and an upper limit of one. Tobit model was applied as indicated in Equation 7.

$$TE_i = \delta_0 + \delta_1 Z_1 + \cdots + \delta_{11} Z_{11} + \omega \quad (7)$$

Where, TE_i= technical efficiency, δ_0 is the intercept of the function while δ_1, δ_2 … δ_{11} are unknown scalar parameters to be estimated. $Z_1, Z_2, Z_3, Z_4, Z_5 Z_6, Z_7 Z_8, Z_9, Z_{10}$ and Z_{11} are age, gender, education, family size, farming experience, credit access, farm distance from home, extension services, contract engagement, soil testing before planting and farm record keeping respectively. ω is the error term which is assumed to be normally distributed.

Validity of model assumptions

The hypothesis of homoscedasticity and no multicollinearity in the data set were tested for the validity of model assumptions. Breusch-Pagan and Variance Infation Factors (VIF) were applied respectively to test for the presence of heteroscedasticity and multicollinearity in the data set.

Test of heteroscedasticity

Heteroscedasticity refers to a situation where the assumption that the classical linear regression model has equal variance of residuals is violated. There exists several tests for heteroscedasticity detection such as the Koeker Basset, the White's and the Breusch-Pagan tests among others (Gujarati and Porter, 2009). This study used the Breusch-Pagan with null hypothesis of constant variance for heteroscedasticity. Breusch-Pagan is a chi-squared test whereby if the statistical test gives a p-value that is below suitable threshold of 0.05 then the null hypothesis of homoscedasticity is rejected (Gujarati and Porter, 2009).The calculated chi square value was 0.39, with a p-value of 0.5308 which is greater than 0.05 indicating homoscedasticity in the data set.

Test for multicollinearity

The problem of multicollinearity occurs when one or more of the explanatory variables indicate a linear combination of other variables. This problem can result to wrong signs in the estimated regression coefficients and smaller t-ratios thereby having wrong conclusions. A strong correlation coefficient may be an indicator of this problem and can be examined further by computing VIF for each of the independent variables (Rabe-Hesketh and Everitt, 2000). Following Chatterjee and Price (1991), when values of VIF are greater than 10 or when a mean of the factors (1/VIF) is considerably greater than 1, then there is a problem of multicollinearity which calls for concern. Accordingly, values of VIF were calculated for explanatory variables and were ranging from 1.09 to 3.60 with a mean of 1.85. Furthermore, the mean values of the factors (1/VIF) ranged from 0.278 to 0.919. Multicollinearity was therefore not a problem among the explanatory variables.

RESULTS AND DISCUSSION

Demographic and socio-economic characteristics of the sampled households

Table 1 shows descriptive results of demographic and socio-economic characteristics of selected smallholder sugarcane farmers. The average size of the family in the area of study was 6 people with a minimum of 1 and a maximum of 13 persons implying the availability of labour among smallholder sugarcane farmers. The result showed that on average, respondents have 16 years of experience in sugarcane farming implying that most farmers could provide reliable information and have deep understanding of sugarcane farming. Years of experience amongst respondents ranged from 1 year to 36 years.

Both the youth and elderly were involved in sugarcane farming whereby, majority of respondents (72.66%) were between 21 and 50 years of age which is the most productive age group with active farmers. On the other hand, 27.34% of the respondents were above 50 years of age implying that some areas had less active farmers involved in sugarcane production.

The study indicated that 71.61% of the respondents were male while 28.39% were female indicating that the sugarcane crop is important for both gender. However, most of the respondents were male indicating that decisions in sugarcane production at farm level are mostly made by male gender who are the head of the household. This therefore confirms the worldwide situation whereby women are significantly involved in sugarcane farming activities mainly as casuals but not land owners given their limited access to agricultural resources (Fonjong and Mbah, 2007).

The study indicated that majority of the farmers had formal education where 36.20% of the respondents had secondary education and 15.89% had tertiary education. This high percentage of farmers with formal education imply that majority of farmers were capable of increasing sugarcane productivity through quick understanding of trainings given on the crop management such as best practices and the adoption of new sugarcane production techniques.

Results demonstrated that only 42.19% of the respondents required credit in their production. The majority representing 57.81% of the respondents did not require credit in their production. This imply that majority of farmers were capable of purchasing inputs for sugarcane production and that lack of finance was probably not a limiting factor to most of the smallholder farmers. However, for those who required credit for production, only 64.81% got the credit that they requested for while 35.19% did not get the credit. This imply that some farmers who were in need of credit could not access credit services to enable them purchase production inputs and increase farm productivity.

Majority of respondents (73.96%) have their sugarcane farms less than 1 kilometer from home, making it easier for management and supervision of the farm. Additionally, short distance of sugarcane farms from home implies that help from the family in terms of labour and crop security can easily be provided. However, some farmers (26.04%) had their farms located over 2 km from home making it difficult for proper farm management. The study showed that only 42.97% of the farmers have access to extension services with majority having no access implying that new technologies in sugarcane farming are not disseminated to most farmers. It was however noted that most farmers who have no access to extension services are non-contracted and comprise the majority (65.89%) in the study area.

Only 16.67% of the respondents carry out soil testing before planting of sugarcane. This implies most farmers are not able to know the types and amount of nutrients that are lacking in their soils for enhanced productivity. Knowledge on the soil nutrient status would guide the farmers on the type of fertilizer to apply. Most of the farmers representing 59.38% do not keep records on revenues generated and expenses incurred in the farm activities. This implies that most of the farmers could not determine whether their enterprises were profitable or not.

Descriptive statistics for production variables

The summary statistics for the variables used in estimation of production function and technical efficiency are presented in Table 2. The production function and technical efficiency for this study were estimated using four types of inputs which are the amount of fertilizer, labour, farm size and seed-cane.

The findings in Table 2 shows that on average small scale sugarcane farmers produce 18.69 tonnes of sugarcane per acre which is below the national average yield of about 24 tonnes per acre (Kenya Sugar Board, 2014). This indicates that farmers in the area of study are

Table 1. Demographic and socioeconomic characteristics of the respondents.

Variable	Mean		Std. Dev	Min.	Max.
Family size	6		3.25	1	13
Farming experience	16		8.69	1	36
	Categories		**Frequency**	**Percentage**	
Ages of respondents	21 – 30 years		55	14.32	
	31 – 40 years		89	23.18	
	41 – 50 years		135	35.16	
	Above 50 years		105	27.34	
Gender of respondents	Male		275	71.61	
	Female		109	28.39	
Level of Education of respondents	No formal education		48	12.50	
	Primary		136	35.42	
	Secondary		139	36.20	
	Tertiary		61	15.89	
Credit access	Required credit	Yes	162	42.19	
		No	222	57.81	
	Got credit	Yes	105	64.81	
		No	57	35.19	
Farm distance from home	Less than 1 Km		284	73.96	
	2 – 4 Km		71	18.49	
	Over 4 Km		29	7.55	
Get extension services	Yes		165	42.97	
	No		219	57.03	
Contract engagement	Yes		131	34.11	
	No		253	65.89	
Soil test before planting	Yes		64	16.67	
	No		320	83.33	
Farm record keeping	Yes		156	40.62	
	No		228	59.38	

Table 2. Descriptive statistics for the model variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
Amount of fertilizer (Kgs per acre)	384	308.29	138.85	50	650
Labour (man days per acre)	384	20.58	5.5767	7	41
Sugarcane cuttings (tonnes per acre)	384	2.27	1.20	0.5	9
Farm size (acres)	384	2.80	2.58	0.25	33
Sugarcane yield (tonnes per acre)	384	18.69	10.00	1.5	63

producing below their production potential. The minimum yield of sugarcane obtained is 1.5 tonnes per acre and the maximum is 63 tonnes per acre implying that farmers have a potential of producing up to 63 tonnes per acre. The average values for fertilizer, labour and seed-cane are 308.29 kg, 20.58 man days and 2.27 tonnes per acre

Table 3. Stochastic frontier production function results.

Variable	β-coef.	Std. Err.	Z-Value	P>|z|
Lnfertilizer	0.267***	0.0308	8.67	0.000
Lnlabour	0.626***	0.0774	8.08	0.000
Lnseed cane	0.155***	0.0279	5.57	0.000
lnfarm size	0.146***	0.0232	6.26	0.000
Constant	-0.407**	0.192	-2.12	0.034
Usigma	-1.028***	0.0781	-13.16	0.000
Vsigma	-6.154***	0.419	-14.70	0.000
Diagnostic test				
Sigma u	0.598	0.0233585	25.60	0.000
Sigma v	0.0461	0.0096507	4.78	0.000
Lambda (λ)	12.973	0.0269179	481.95	0.000
Sigma2 (σ^2)	0.360			
Gamma (Υ)	0.994			
Log likelihood	-101.136			
Prob > chi2 = 0.0000				

***significant at 1% and **significant at 5%.

respectively. The average farm size allocated to sugarcane production for households was 2.80 acres. This implies that sugarcane in the area of study is on average grown in small scale farms.

Estimation of parameters of the frontier production function

Table 3 shows the findings of the stochastic frontier analysis. The parameters of fertilizer, labour, seed-cane and farm size were found to be significant at 1% level with the estimated β-coefficients of 0.267, 0.626, 0.155 and 0.146 respectively. The results imply that 1% increase in the amount of fertilizer used increases sugarcane output by 0.267% and 1% increase in labour use increases sugarcane output by 0.626%. Moreover, an increase of improved seed-cane by 1% would increase output by 0.155%. On the other hand, 1% increase in farm size increases sugarcane yield by 0.146%. The results are in line with the economic theory of production and concur with the findings by Wawire and Ouma (2013) who found out those sugarcane farmers were not maximizing their production yields.

The findings on the effect of farm size on sugarcane production in the current study were in line with those of Khan et al. (2010) and Baruwa and Oke (2012) in Bangladesh and Nigeria respectively. However, these results were in contradiction with the results by Tchale (2009) which showed a negative influence of farm size on technical efficiency in Malawi. The latter study however associated the negative effect with operating beyond the optimal scale of the land where production was carried out on larger farms than what a farmer could manage. Thus, in Kenya the size of sugarcane farms can still be managed and increase in sugarcane farm area would increase production. However, farm expansion should be carried out with care as Anyaegbunam et al. (2012) found out in their study that farm size may inversely increase with technical efficiency. Since all the four inputs were positive and significant, it is indicated that these factors significantly determine sugarcane output in the study area.

The findings in Table 3 indicate that the value of lambda (λ) is 12.973 indicating that in total deviation 12.973% difference between observed and potential yield is due to the inefficiency among the sampled respondents. The parameter gamma (γ) value is 0.994 which is very close to one. This parameter is usually associated with the two error terms of the stochastic frontier function (Battese and Coelli, 1995). This parameter measures the deviation of the output from the frontier caused by the effect of inefficiency and it equals to $\sigma^2\mu/ (\sigma^2 v + \sigma^2\mu)$ whereby $\sigma^2\mu$ and $\sigma^2 v$ represent the variances related to technical inefficiency and statistical noise respectively. The values therefore indicated that 99.4% variations in the composite error terms was caused by inefficiency effects. Additionally, the estimated value of sigma squared (σ^2) is 0.3597, which is significantly greater than zero, indicating the appropriateness of the model. The log likelihood statistic also shows the appropriateness of the model given it is significant at 1% level and the large

Table 4. Frequency distribution of technical efficiency estimates.

Technical efficiency range	Frequency	Percentage
0.0 – 0.20	12	3.13
0.21 – 0.40	30	7.81
0.41 – 0.60	54	14.06
0.61 – 0.80	142	36.98
0.81 -0.99	146	38.02
Mean (0.7069)		
Minimum (0.000465)		
Maximum (0.9829)		

Table 5. Tobit regression analysis results.

Variable	Coef.	Std. err.	t-value	P value
Age	-0.0726***	0.0155	-4.70	0.000
Gender	0.0109	0.0190	0.58	0.564
Education	0.0213**	0.0108	1.98	0.049
Family size	0.0240***	0.00403	5.95	0.000
Farming experience	0.00429**	0.00177	2.41	0.016
Credit access	0.0596***	0.0203	2.94	0.003
Farm distance from home	-0.0982***	0.0140	-7.02	0.000
Extension services	0.105***	0.0192	5.46	0.000
Contract engagement	-0.0938***	0.0213	-4.41	0.000
Soil testing before planting	0.0476**	0.0241	1.97	0.049
Farm record keeping	0.0153	0.0199	0.77	0.442
Constant	0.797***	0.0572	13.95	0.000
Sigma	0.161***	0.00582		
Log likelihood		155.53		
Prob > chi2 = 0.0000				

***significant at 1% and **significant at 5%.

absolute value of Log Likelihood ratio of -101.136.

Technical efficiency among sugarcane farmers

The results of the frequency estimates of the technical efficiency are shown in Table 4. The findings indicated that majority of respondents recorded below 0.81 level of technical efficiency. This shows that most of the smallholder sugarcane farmers are technically inefficient. The results also showed that farmers are operating at an average technical efficiency of 0.7069 ranging from a minimum of 0.000465 to a maximum of 0.9829. This wide variation in technical efficiency estimates indicates that majority of the farmers are inefficiently utilizing their resources in the production process and there are opportunities for increasing their current yield by improving technical efficiency. An average farmer is operating at 70.69% below the production frontier due to inefficiency effects. This complemented the results from the hypothesis testing showing that on average, the frontier production is not yet attained due to significant inefficiency effects. This could be attributed to misuse and/or wastage of inputs. Similar results were reported by Kassa et al. (2019) and Nyagaka et al. (2010).

Factors affecting technical efficiency among sugarcane farmers

Table 5 shows the tobit regression results for the relationship between the selected socioeconomic factors and technical efficiency. The log likelihood statistic which determines the appropriateness of the model indicates that the model is applicable given its significant chi-square (p<0.000) and the large absolute value of Log Likelihood ratio of 155.53.

The findings presented in Table 5 shows that, the level of education, farming experience and soil testing before planting are positive and significant at 5% level. Family size, access to extension services and access to credit are positive and significant at 1% level. However, age of the farmer and contract engagement were found to be negative and significant at 1% level. Gender and farm record keeping were positive but insignificant at all levels.

Age variable depicted a negative effect on technical efficiency where an increase of age by 1% would reduce technical efficiency by 0.0726%. This showed that the older a farmer become, the higher the technical inefficiency in sugarcane production. Age of the farmer can take a positive sign when older farmers are willing to adopt improved methods thus increasing technical efficiency effects or when knowledge, skills and the experience gained during their years of farming contribute in reducing inefficiency. This variable can take a negative sign like in the current study, indirectly showing that older farmers are resistant to adopt improved technologies and that they lack mental and physical capacity to efficiently participate in sugarcane production. Similar results were found by Khan and Saeed (2011) who argued that older farmers are less technically efficient than younger farmers, showing that the more the younger farmers get educated the more efficient they become. On the contrary, Getahun and Geta (2017) and Binam et al. (2004) assumed that when farmers get old, they become more experienced and efficient. Then again, higher technical efficiency is attained by the age group which have more interest in the type of crop being cultivated (Thabethe and Mungatana, 2014).

The level of education is positive and significant indicating that 1% increase in the level of education would increase technical efficiency by 0.0213%. This relationship is significant at 1% level. This means that when farmers are educated on the suitable techniques of farming as well as resource use, they become more efficient. This finding concur with those of Weir and Knight (2007) who found out that there was a positive relationship between the level of education and efficiency among small scale farmers. A study by Sulaiman et al. (2015) on resource use efficiency among sugarcane farmers in Nigeria indicated that farmers who are more educated quickly acquire new technologies and produce more output which is closer to the production frontier.

Family size indicated a positive relationship with the technical efficiency as expected. From Table 5, it is shown that 1% increase in family size increases the technical efficiency by 0.024%. Large family size is associated among other factors with availability of cheap labour. Sugarcane production is a labour intensive activity and hence a large family size is assumed to provide cheap labour. These results concur with those of Mailena et al. (2014), Sulaiman et al. (2015) and Ahmad et al. (2018). However, the results by Kadiri et al. (2014) showed a negative relationship between family size and technical efficiency of paddy rice production in Nigeria. On the other hand, Ali and Jan (2017) and Getahun and Geta (2017) showed that there was insignificant effect of this variable on technical efficiency. This variable therefore needs more research on its effect on technical efficiency in order to make a reliable conclusion.

The findings on farming experience revealed a positive relationhip with technical efficiency. An increase in the level of experience by 1% increases sugarcane yield by 0.00429%. High farming experience is associated with increased proficiency in the processes of farm production and hence inreased productivity. Similar results were found by Nyagaka et al. (2010) in their analysis of economic efficiency in Irish potato production in Kenya. Mulwa et al. (2014) and Mburu et al. (2014) showed the same relationship between farming experience and efficiency among smallholder maize farmers in Western Kenya and Nakuru District in Kenya respectively.

Credit access revealed a positive and significant relationship with technical efficiency among sugarcane farmers. Access to credit is an important source of capital which enables smallholder sugarcane producers to purchase production inputs on time thereby increasing farm productivity. It enables the farmer to adopt new technologies and practices through easing farmers liquidity constraints (Ike and Inoni, 2006). This variable was hypothesed to have a positive effect on technical efficiency which was confirmed by findings. The findings were similar to those by Kibaara (2005) and Sulaiman (2015) who found a positive relationship between access to credit and technical efficiency.

Extension services showed a positive and significant relationship with technical efficiency where a farmer could increase technical efficiency 10.5% by adopting these services. This implied that access to extension services by sugarcane farmers contribute to technical efficiency in production of sugarcane. The positive effect of extension services on technical efficiency could be linked to the information and knowledge received by sugarcane farmers which complement the trainings. These findings were consistent with those of Nchare (2007) and Simonyan et al. (2011). In contrast, Ezeh et al. (2012) found out that extension services had a negative effect on technical efficiency which was not expected and they recommended further research to be conducted on the same.

Farm distance from home showed a negative relationship with technical efficiency implying that nearer farms can be efficiently managed as compared to farther farms. The more the distance of sugarcane farm from home, the more the difficulty in farm management andhence low productivity. The findings were in line with those of Mamo et al. (2018). Contract engagement also showed a negative relationship with technical efficiency. These findings on the contract engagement concur with those of Waswa et al. (2012), Sopheak (2015) and Musungu and Sorre, (2017). The negative effect on technical efficiency may be attributed among other factors to increased input prices and harvesting of canes before maturity. On the contrary, the results by Hu (2013) and Igweoscar (2014) showed a positve and significant effect of contract engagement on technical efficiency. This variable therefore needs more investigation since farmers enter into contract engagement with the aim of increasing their productity which the current study has revealed otherwise.

Soil test before planting is an important practice which helps farmers to identify the type of nutrients needed in the soils as well as the type of crops appropriate in the area. The study showed a positive relationship of this variable with technical efficiency as expected. It showed that adoption of this practice increases technical efficiency by 4.76%. The results are consistent with the recommendations by Jamoza et al. (2013) and Amolo et al. (2017).

Conclusion

The results of this study showed that smallholder sugarcane farmers are inefficient with a mean technical efficiency of 0.7069. There is high variation of technical efficiency between smallholder sugarcane farmers in the Country. The maximum likelihood estimates indicated that fertilizer, labour, seed-cane and farm size make significant contribution in improving the productivity of sugarcane among smallholder farmers. The study tested a null hypothesis that socioeconomic factors have no effect on technical efficiency among smallholder sugarcane farmers. The findings revealed that age, education, farming experience, family size, access to extension services, access to credit, contract engagement and soil testing before planting were significantly affecting technical efficiency. Therefore, the null hypothesis is rejected in favor of the alternative that socioeconomic factors have effect on technical efficiency among smallholder sugarcane farmers.

Reccommendations

The findings of the study revealed that there exist an opportunity to increase sugarcane production at the existing level of inputs use and level of technology. The study therefore came up with the following recommendations to guide farmers, policy makers as well as researchers for further investigations.

1. The Kenyan government should ensure the provision of quality extension services to smallholder sugarcane farmers for increased productivity since this variable was found to have great positive impact on productivity of sugarcane among smallholder farmers.
2. Contract engagement is meant to improve productivity of farmers. However, this study has revealed that contract engagement is negatively affecting technical efficiency. As such, the Kenyan government should review policies on contract engagement with contract service providers to change this situation.
3. Some of the farmers in the area of study achieved high yield and obtained high technical efficiency and hence such farmers can be used effectively to illustrate the usefulness of good farming practices in order to reduce the gap that exists between the most technically efficient and the most inefficient farmers.
4. Sugarcane farmers should establish a formal and active association to represent their right interest so as to help them to acquire new and current information about sugarcane cultivation, access to credit, technical supports and rights on contract engagement from the government and other stakeholders like sugar factories.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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